Optimal use of biomass — for heat, process heat, electricity or as a liquid fuel in the transportation sector?

Christian Azar*, Kristian Lindgren and Björn A. Andersson
Department of Physical Resource Theory, Chalmers University of Technology, Göteborg University
SE-412 96 Göteborg, SWEDEN
Fax: +46-31-772 3150; frtca@fy.chalmers.se

Governmental policies and international treaties that aim at curbing the emissions of greenhouse gases and local pollutants can be expected. These regulations will increase the competitiveness of CO_2-neutral energy sources, i.e., biomass, solar, wind, hydro, nuclear or fossil fuels with CO_2-sequestration. Biomass energy is a promising option since biomass can be produced at a low cost, and be converted into essentially any energy carrier (electricity, hydrogen, heat or liquid biofuels such as methanol or ethanol). But biomass resources are not large enough to satisfy the global energy demand. Thus, we must ask ourselves in which sector should we use our biomass resources?

In this paper, we have developed an energy systems model (linear programming) with an explicit transportation module, a heat/process heat module and electricity module. The transportation module is the most detailed one (it has costs for fuel cells, reformer and storage tank, infrastructure, flexibility in fuel supply). The model is then run under the assumption that atmospheric concentrations of CO_2 should be stabilised at 400 ppm.

Several interesting results emerge: (i) biomass is primarily used for the heat/process heat sectors, (ii) despite the stringent CO_2 constraints, oil-based fuels remain dominant in the transportation sector over the next 50 years, and (iii) once a transition towards alternative fuels takes place, because of the increasingly stringent CO2 constraints, the preferred choice of fuel in the transportation sector is hydrogen produced from solar and decarbonized fossil fuels. This latter result holds even if we assume that hydrogen fuel cell vehicles are substantially more costly than methanol fuel cell vehicles. Detailed sensitivity analyses with respect to a number of important parameters are carried out.

The primary energy supply in the base case of the model is illustrated in Figure 1. For the first half of the century we note that the restrictions on emissions still allow for a continued use of oil and natural gas. The use of coal may not expand though, and the increased demand for energy is met by an expansion of the biofuel supply, reaching the limit of 200 EJ/year, that we have assumed in the model, around the middle of the century. During the second half of the century a continued increase of energy demand must be met by other, more expensive, technologies, unless biofuel supply can increase further. In the model, there are two main technologies that can be invoked, decarbonisation applied to use of coal (for production of electricity, heat, or hydrogen) and solar generated hydrogen. In which way these technologies enter depend of course on cost and efficiency parameters which are very uncertain at this point. The decline of oil and natural gas is due to the assumed limited reserves of these fossil fuels.

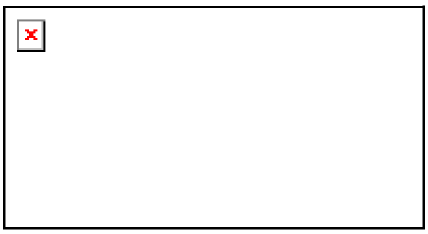

Figure 1. World primary energy supply. The three solar energy technologies used in the model (H2, EL, HT) produce hydrogen, electricity (e.g., PV), and heat (for processing and heating), respectively. The bio fuel supply grows to reach the limit of 200 EJ/year assumed in the model.